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Ultrahard materials through surface heat treatment

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ABSTRACT

Ultrahard materials that are chemically inert and thermally stable at high temperatures are desirable for enhancing machining and wear performance in demanding chemical and thermal environments. Single and polycrystalline diamonds are the hardest materials (75–100 GPa); however, at high temperatures, diamond loses its chemical inertness and thermal stability. In contrast, cubic boron nitride (cBN) has exceptional chemical and thermal stability but has much lower hardness (35–45 GPa). Increasing the hardness of BN to the level of diamond is expected to result in chemically and thermally inert ultrahard material that is suitable for range of demanding wear and machining applications. An innovative laser/waterjet heat treatment (LWH) technique was designed and applied to polycrystalline 50% cBN/50% wBN tool inserts to reach the hardness level of polycrystalline diamond. The LWH processing consisted of surface heating samples using a continuous wave CO_2 laser beam followed by tandem waterjet quenching of the laser beam path to cause stress-induced microstructural changes. Dispersive Raman spectroscopy, high-resolution scanning electron microscope and surface grazing XRD were used to identify the BN phase signatures, grain size changes, and phase transitions. The laser-waterjet heat treatment increased the hardness of binderless cBN sample by 20% (nominal 60 GPa) while it increased the hardness of binderless cBN/wBN sample by 100% (nominal 75 GPa) reaching the hardness of polycrystalline diamond (65–80 GPa). Microstructural analysis of the samples revealed three major features due to heat treatment. First is the formation of amorphous phase as noted by presence of the interfacial layer at grain boundaries. Such phase is expected to introduce the grain-boundary strengthening mechanism via inhibiting ease of dislocation movement across the boundary. Second is the formation of zones with nanosized grains that are expected to increase the energy needed to introduce plastic deformation. Third is the extensive fragmentation and cracking of the lamellas that also reduced the effective grain size and may contribute to the strengthening. A combination of amorphous phase formation at the grain boundaries and nanosized grain formation are suggested as the mechanisms responsible for the increased hardness.